EXPERTISE IS ONLY AN ADVANTAGE IN THE EXPERT'S SPECIALTY

Although there are many differences between experts and novices, it appears that these differences hold only when problems are within an expert's field. When James Voss and coworkers (1983) posed a real-world problem involving Russian agriculture to expert political scientists, expert chemists, and novice political scientists, they found that the expert political scientists performed best and that the expert chemists performed as poorly as the novice political scientists. In general, experts are experts only within their own field and perform like anyone else outside of their field (Bedard & Chi, 1992). This makes sense when we remember that the superior performance of experts occurs largely because they possess a larger and better organized store of knowledge about their specific field.

Before leaving our discussion of expertise, we should note that being an expert is not always an advantage. One disadvantage is that knowing about the established facts and theories in a field may make experts less open to new ways of looking at problems. This may be why younger and less experienced scientists in a field are often the ones responsible for revolutionary discoveries (Kuhn, 1970; Simonton, 1984). Thus, it has been suggested that being an expert may be a disadvantage when confronting a problem that requires flexible thinking—a problem whose solution may involve rejecting the usual procedures in favor of other procedures that might not normally be used (Frensch & Sternberg, 1989).

Creative Problem Solving

There's a story about a physics student who, in answer to the exam question "Describe how the height of a building can be measured using a barometer," wrote "Attach the barometer to a string and lower it from the top of the building. The length of string needed to lower the barometer to the ground indicates the height of the building." The professor was looking for an answer that involved measuring barometric pressure on the ground and on top of the building, using principles learned in class. He therefore gave the student a zero for his answer.

The student protested the grade, so the case was given to another professor, who asked the student to provide an answer that would demonstrate his knowledge of physics. The student's answer was that the barometer could be dropped from the roof measuring how long it took to hit the ground. Using a formula involving the gravitational constant it would be possible to determine how far the barometer fell. With further prodding from the appeals professor the student also suggested another solution: Put the barometer in the sun and measure the length of its shadow and the length of the building's shadow. The height of the building could be determined using proportions.

Upon hearing these answers, both of which could result in correct solutions, the appeals professor asked the student whether he knew the answer the professor was looking for, which involved the principle of barometric pressure. The student replied that he did, but was tired of just repeating back information to get a good grade (Lubart & Mouchiroud, 2003).

There are a number of points to this story, one of which is that sometimes being too creative can get you into trouble. But the main point is that this student's answers to the professor's question, although perhaps not what the professor was looking for, surely qualified as being creative. The definition of creativity is hard to pin down, but most people would agree that it involves innovative thinking, generating novel ideas, or making new connections between existing ideas to create something new (Csikszentmihalyi, 1996; Ward et al., 1995, 1997).

Creativity is often associated with **divergent thinking**—thinking that is open-ended, involving a large number of potential "solutions" and no "correct" answer (although some proposals might work better than others; see Guilford, 1956; Ward et al., 1997).

Divergent thinking can be contrasted with convergent thinking, which is thinking that works toward finding a solution to a specific problem that usually has a correct answer. In this case, thinking *converges* on the correct answer. Divergent thinking is most closely associated with ill-defined problems and convergent thinking with well-defined problems (see page 326).

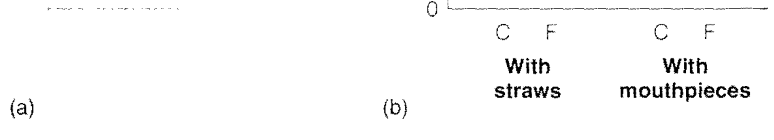
Although creativity is highly valued in our society and has been responsible for many inventions and scientific discoveries, we have only a limited understanding of the processes involved in creativity. We do know, however, that some of the principles we have discussed with regard to problem solving in general also operate during the creative process.

In our earlier discussion of Gestalt psychologists' research on obstacles to problem solving, we discussed fixation. An example of how fixation almost derailed a promising project occurred when Sony temporarily abandoned work on music CDs in the mid-1970s because the 18 hours of music that could potentially fit on a CD the size of the 12-inch diameter long-playing records in use at the time was not considered commercially viable. Their problem was that they were fixated on the current medium of recorded music, taking as their starting point the LP record. Once they overcame that fixation and realized that CDs could be smaller, they returned to the project and revolutionized the music industry (Ward, 2004).

David Jansson and Steven Smith (1991) studied the effect of fixation on creative design by presenting engineering design students with design problems and telling them to generate as many designs as possible in 45 minutes. One of the problems was to design an inexpensive, spill-proof coffee cup. It was specified that the design could not include a straw or mouthpiece. Half the students were assigned to the "fixation group" and were presented with a sample design like the one in ● Figure 12.20a, which they were told illustrated what *not* to do. Notice that this sample design includes a mouthpiece and straw—two features specifically forbidden by the design specifications. Another group of students, the control group, was given the same task and specification, but did not see a sample design.

The average number of designs per person was approximately the same for the two groups, but the fixation group's designs included many more instances of cups with straws and mouthpieces (Figure 12.20b). Apparently, they were influenced by the sample design, even though they were told not to include straws or mouthpieces. This effect, which Jansson and Smith call **design fixation**, is analogous to the Gestalt psychologists' demonstrations of how fixation can inhibit problem solving (see page 329).

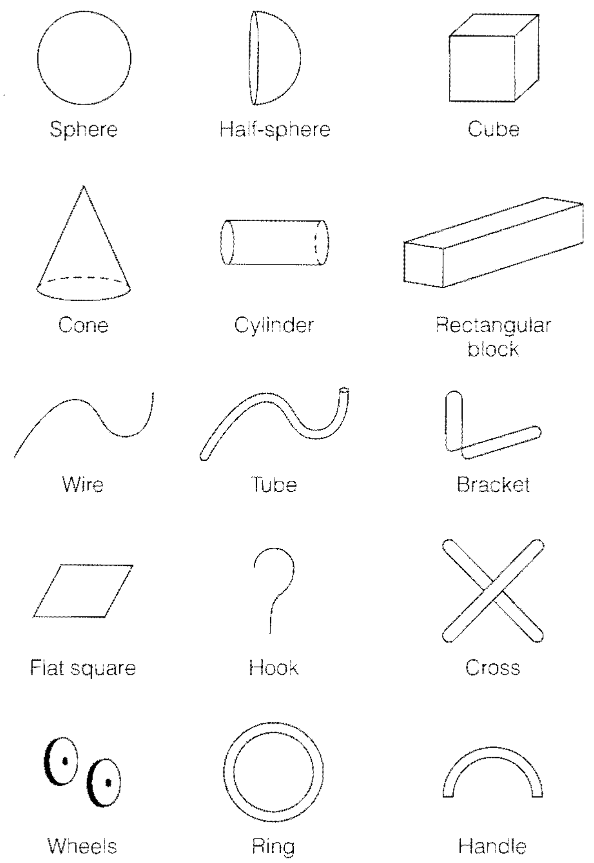
Another carryover from our discussion of problem solving to creativity is the process of analogical thinking. A famous example is the story of George de Mestral, who in 1948 went for a nature hike with his dog and returned home with burrs covering his pants and the dog's fur. To discover why the burrs were clinging so tenaciously, de Mestral inspected the burrs under a microscope. What he saw was many tiny hooklike structures, which led him to design a fabric fastener with many small hooks on one side and soft loops on the other side. In 1955 he patented his design and called it Velcro!



● **FIGURE 12.20** (a) Sample design for coffee cup. (b) Percentage of designs with straws and mouthpieces for the control group (C), which didn't see the sample design, and the fixation group (F), which did. (Source: Based on D. G. Jansson & S. M. Smith, "Design Fixation," *Design Studies, 12,* 3-11, 1991. Reprinted by permission of Elsevier.)

This story illustrates not only how analogy stimulated a new invention but that coming up with the initial idea is often just the beginning of the creative process. It took de Mestral 7 years of trial and error to transform his innovative insight into a marketable product. Creativity therefore involves having unique insights and also being able to follow through to transform that insight into a product—be it a work of art, an idea for a scientific experiment, or a commercially viable invention.

Although de Mestral was a particularly creative individual, you don't have to be a famous inventor to be creative. Cognitive psychologist Ronald Finke developed a technique called creative cognition to train people to think creatively. The following demonstration illustrates Finke's technique.



● **FIGURE 12.21** Objects used by Finke (1990, 1995). (Source: R. A. Finke, "Creative Insight and Preinventive Forms," Figure 8.1, in R. J. Sternberg & J. E. Davidson, Eds., *The Nature of Insight*, pp. 255–280, Cambridge, MA: MIT Press, 1995. Copyright © 1995 MIT Press. Reproduced with permission from the MIT Press.)

DEMONSTRATION Creating an Object

● Figure 12.21 shows 15 object parts and their names. Close your eyes and touch the page three times, in order to randomly pick three of these object parts. After reading these instructions, take 1 minute to construct a new object using these three parts. The object should be interesting-looking and possibly useful, but try to avoid making your object correspond to a familiar object, and don't worry what it might be used for. You can vary the size, position, orientation, and material of the parts, as long as you don't alter the basic shape (except for the wire and the tube, which can be bent). Once you come up with something in your mind, draw a picture of it.

This exercise is patterned after one devised by Ronald Finke (1990, 1995), who randomly selected three of the object parts from Figure 12.21 for his participants. After the participants had created an object, they were provided with the name of one of the object categories from Table 12.4 and were given 1 minute to interpret their object. For example, if the category was tools and utensils, the person had to interpret their form as a screwdriver, a spoon, or some other tool or utensil. To do this for your form, pick a category, and then decide what your object could be used for and describe how it functions. ● Figure 12.22 shows how a single form that was constructed from the half-sphere, wire, and handle could be interpreted in terms of each of the eight categories in Table 12.4.

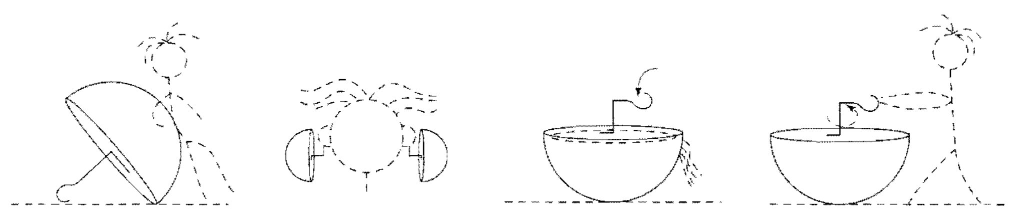
Finke called these "inventions" *preinventive forms* because they are ideas that precede the creation of a finished creative product. Just as it took de Mestral years to develop Velcro after his initial insight, preinventive forms need to be developed further before becoming useful "inventions."

In an experiment in which participants created 360 objects, a panel of judges rated 120 of these objects as being "practical inventions" (the objects received high ratings for "practicality") and rated 65 as "creative inventions" (they received high ratings for both practicality and originality; Finke, 1990, 1995). Remarkably, Finke's participants had received no training or practice, were not preselected for "creativity," and were not even told they were expected to be creative.

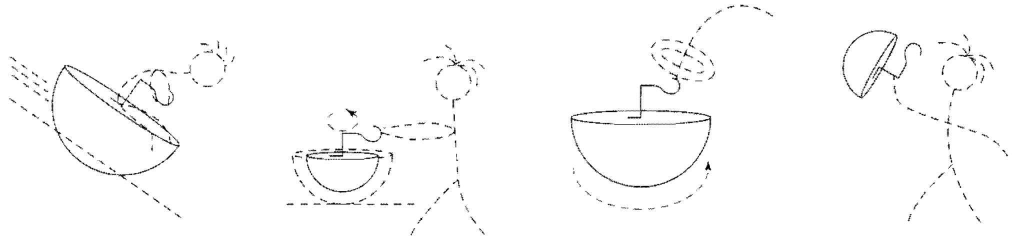
TABLE 12.4 Object Categories in Preinventive Form Studies

Category	Examples
1. Furniture	Chairs, tables, lamps
2. Personal items	Jewelry, glasses
3. Scientific instruments	Measuring devices
4. Appliances	Washing machines, toasters
5. Transportation	Cars, boats
6. Tools and utensils	Screwdrivers, spoons
7. Toys and games	Baseball bats, dolls
8. Weapons	Guns, missiles

Adapted from Finke, 1995.



(1) Lawn lounger (2) Global earrings (3) Water weigher (4) Portable agitator



(5) Sled (6) Rotating masher (7) Ring spinner (8) Slasher basher

FIGURE 12.22 How a preinventive form that was constructed from the half-sphere, wire, and handle can be interpreted in terms of each of the eight categories in Table 12.4. (Source: R. A. Finke, "Creative Insight and Preinventive Forms," Figure 8.6, in R. J. Sternberg and J. E. Davidson, eds., *The Nature of Insight*, pp. 255-280. Copyright © 1995 MIT Press. Reproduced with permission from the MIT Press.)

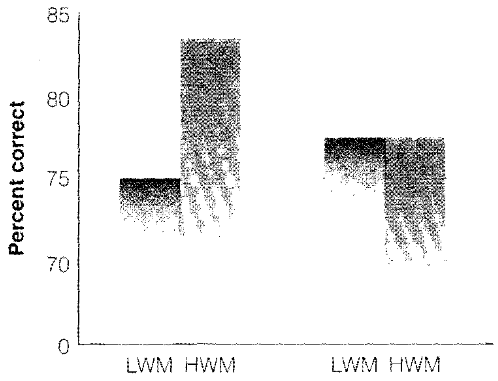
Finke demonstrated not only that you don't have to be an "inventor" to be creative, but also that many of the processes that occur during creative cognition are similar to the cognitive process from other areas of cognitive psychology. For example, Finke found that people were more likely to come up with creative uses for preinventive objects that they had created themselves than for objects created by other people. This occurred even though participants were instructed not to consider uses for the forms as they were creating them. This result is similar to the generation effect we discussed in Chapter 7—people remember material better when they generate it themselves (page 178). This advantage for self-generated material also occurs for retrieval cues (page 183).

Another relevant cognitive principle is the idea that fixations can inhibit problem solving. Having participants combine objects rapidly and without reference to uses lessens the chance that fixations, caused by prior experience, will inhibit creativity. Although there is certainly something special about creativity, it appears we can understand some aspects of creativity in terms of general cognitive principles.

Something to Consider

DOES LARGE WORKING MEMORY CAPACITY RESULT IN BETTER PROBLEM SOLVING? IT DEPENDS!

Having high working memory capacity is generally considered to be a good thing. We saw in Chapter 5 that high working memory capacity is associated with higher intelligence and good performance on comprehension tests. (See Something to Consider: The Advantages of Having a More Efficient Working Memory, page 141.) It would therefore seem to follow that people with high working memory capacity should be better at solving problems. It turns out that this is true under some, but not all, conditions.



(a) Low pressure (b) High pressure

FIGURE 12.23 Mathematics problem-solving performance for high working memory and low working memory participants under (a) low pressure and (b) high pressure conditions. High working memory participants performed better under low pressure conditions but lost their advantage under high pressure. (Source: Based on S. L. Beilock & T. H. Carr, "When High-Powered People Fail," *Psychological Science, 16,* 101–105, 2005.)

First, let's consider when it is an advantage to have high working memory capacity. Sian Beilock and Thomas Carr (2005) investigated the relationship between working memory capacity and mathematical problem solving by first measuring participants' working memory capacity (see Method: Reading Span, page 142) to divide them into low working memory (LWM) and high working memory (HWM) groups. Then they presented participants with a modular arithmetic problem. Modular arithmetic problems are stated as follows: 51≡19 (mod 4). One way to solve the problem is by subtracting the second number from the first (51 – 19) and then dividing by the last number (32 divided by 4). The task is to respond "True" if the answer is a whole number (which would be the case in this example) or "False" if there is a remainder.

Figure 12.23a shows the results for participants who were simply told to try their best on the task. These instructions were worded to create no pressure, so this was called the "low pressure condition." In this condition, HWM participants performed better than the LWM participants.

Figure 12.23b shows the results for participants who were given instructions calculated to create a great deal of pressure to perform well. These instructions indicated that they would receive money for increasing their score above a target level, that they had to perform well in order for another person "on their team" who had already done well to receive money, and that they were being videotaped so math teachers could examine their performance. The net result of these instructions, which created the "high pressure condition," was to increase feelings of pressure and anxiety. It is clear from the results for this condition that the increase in pressure had no effect on the performance of LWM participants but caused a decline in the performance of HWM participants, effectively eliminating the advantage they had in the low pressure condition.

Why would HWM participants "choke under pressure," while LWM participants didn't? The answer appears to be related to the fact that people with high working memory generally favor complex strategies for solving problems. When pressure is low, HWM participants are therefore more likely to work through each problem using the subtraction and division procedure described above. Beilock calls this the "algorithm" procedure because it is a step-by-step procedure that is guaranteed to result in the correct answer, if applied correctly (see page 62 for more on algorithms). In contrast, LWM participants are more likely to use a simpler "shortcut strategy" such as a rule like "Both numbers are even, so the result of subtraction would be even and probably divisible by the mod number."

Thus, under low pressure, the HWM participants have an advantage because they have enough working memory to do the more complex and more accurate calculation, but when under high pressure, these participants switch to faster but less accurate rules (Beilock & DeCaro, 2007). This switch to the less accurate procedure is why the HWM advantage vanishes under high pressure conditions.

Why should increasing the pressure cause HWM participants to switch strategies? One reason might be that the pressure and the anxiety it creates cause the HWM participants to use more of their WM to deal with their anxiety, and this effectively robs them of the working memory advantage that enabled them to use the more complex algorithm (DeCaro et al., 2010). Beilock (2008) describes this "choking under pressure" effect in terms of *distraction*, much like what occurs when a person is trying to pay attention to two things at once (see Divided Attention, page 91). According to this idea, anxiety caused by stress competes for WM capacity that under less stressful conditions could be focused solely on the math problem.

Given these negative effects of stress on HWM participants, it is important to ask whether there are ways to combat this problem. One possibility is to use strategies that direct attention away from the stress. Marci DeCaro and coworkers (2010) tested this idea by having participants verbalize the steps they were using to solve the problems, as

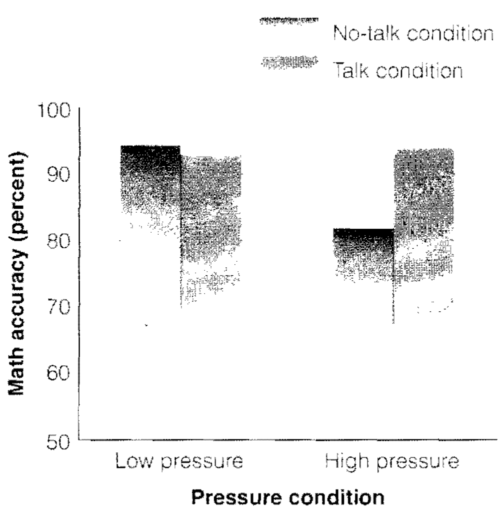


FIGURE 12.24 The effect of talking out loud during problem solving. *Left pair of bars*: No effect of talking under low pressure conditions. *Right pair of bars*: Pressure causes a decrease in performance for the no-talk condition, but not for the talk condition. (Source: M. S. DeCaro, K. E. Rotar, M. S. Kendra, & S. L. Beilock, "Diagnosing and Alleviating the Impact of Performance Pressure on Mathematical Problem Solving," *Quarterly Journal of Experimental Psychology, 16*, published online February 5, 2010.)

they were working on the problems (see Method: Think-Aloud Protocol, page 338). The idea is that talking should focus the person's attention on the problem and away from the stress. The results of this experiment are shown in Figure 12.24, which compares the performance of a group of participants who described what they were doing as they were solving the problem (the talk group) with that of a group that did not describe what they were doing (the no-talk group).

The left pair of bars shows that there was no difference in performance between the talk and no-talk groups under low pressure conditions. The right pair of bars shows that increasing the pressure caused a decrease in performance in the no-talk group, but didn't affect the performance of the talk group. Thus, carrying out a task that focuses attention on solving the problem and distracts attention away from the stress-producing situation is one way to combat the negative effects of stress. Although DeCaro did not separate her participants into HWM and LWM groups, she suggests that this procedure would probably be especially effective for people with high working memory.

Another technique that has been suggested for combating the effects of stress is *practice*. Beilock and Carr (2001) have shown that practicing a golf putting task while being videotaped eliminates choking when performing the task under pressure. In another experiment, participants who practiced math problems before taking a test were less affected by stress (Beilock et al., 2004). The idea that practice should reduce the effect of stress makes sense. After all, "studying" is a form of practice, and it seems likely that people who really know the material because they have studied will be less affected by stress. But more research is needed to determine under what conditions practice helps, what kinds of tasks are most helped by practice, and the kinds of practice that are most effective.

TEST YOURSELF 12.2

1. What is the basic idea behind analogical problem solving? How effective is it to present a source problem and then the target problem, without indicating that the source problem is related to the target problem?
2. What are the three steps in the process of analogical problem solving? Which of the steps appears to be the most difficult to achieve?
3. How do the surface features and structural features of problems influence a person's ability to make effective use of analogies in problem solving? Describe experiments relevant to this question, and also techniques that have been used to improve analogical problem solving.
4. What is the analogical paradox? How has analogical problem solving been studied in the real world?
5. What is an expert? What are some differences between the way experts and nonexperts go about solving problems? How good are experts at solving problems outside of their field?
6. What is convergent thinking? What is divergent thinking? How are these two types of thinking related to creativity? Describe experiments that have shown (a) how fixation can affect creativity; (b) de Mestral's use of analogy to invent Velcro; and (c) Finke's creative cognition procedure.
7. Under what conditions are people with high working memory capacity better at solving math problems than are people with low working memory capacity? Under what conditions do they lose this advantage? Why does this probably occur?